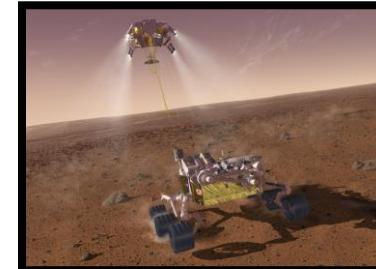




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Model-Driven Development For PDS4 Software And Services

Steven Hughes, Daniel Crichton, Stirling Algermissen,
Michael Cayanan, Ronald Joyner, Sean Hardman, and Jordan Padams
NASA Jet Propulsion Laboratory (JPL),
California Institute of Technology

Planetary Science Informatics and Data Analytics (PSIDA)
Washington University, St. Louis, MO - April 24-26, 2018

Data Architectures, Management, And Data Technologies
Tuesday, April 24, 2018 - 12:05 pm



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Topics

- Overview of the Information Model
- Model-driven benefits provided to the system
 - *Provides the system's information requirements*
 - *Enables interoperability across the community*
 - *Allows extensions for new missions and projects*
 - *Reduces the impact of change*
- Applications
- Conclusion



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Information Model

- “An information model is a representation of concepts, relationships, constraints, rules, and operations to specify data semantics for a chosen domain of discourse.” ¹
- It provides a sharable, stable, and organized structure of information requirements or knowledge for the domain context.

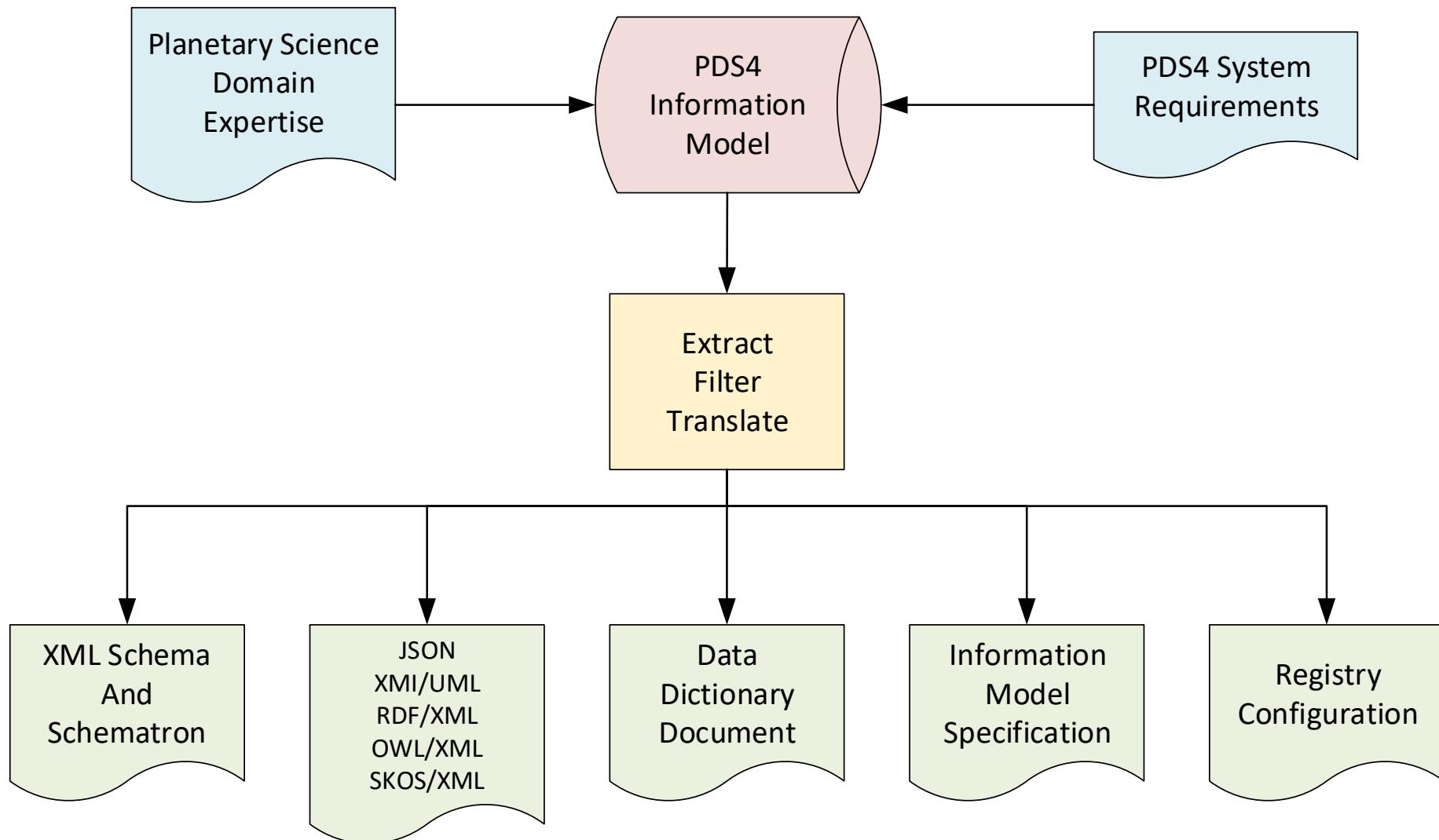
¹ Lee, Y. T. 1999. Information Modeling: From Design To Implementation. In Proceedings of the Second World Manufacturing Congress, ed. S. Nahavandi and M. Saadat, 315-321. Canada/Switzerland: International Computer Science Conventions.



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The PDS4 Information Model





Background

- Developed using:
 - lessons learned from 20 years worth of archiving
 - best practices for information model development
- Foundational principles adopted from:
 - Open Archival Information System (OAIS) Reference Model - ISO 14721 - Foundational Principles
 - ISO/IEC 11179 - Volume 3 – Metadata Registry Specification - Hierarchy of data dictionaries and governance model.
 - W3C XML (Extensible Markup Language) - Rules for encoding documents electronically.

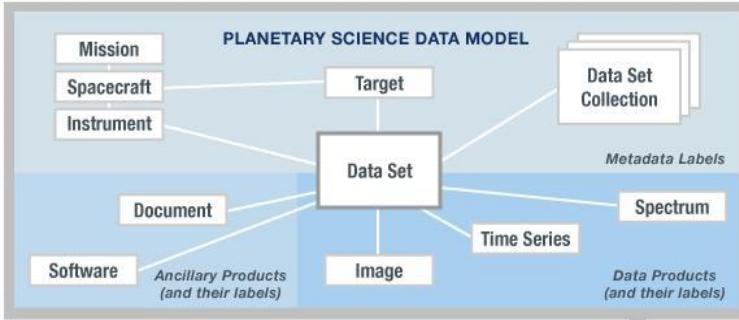


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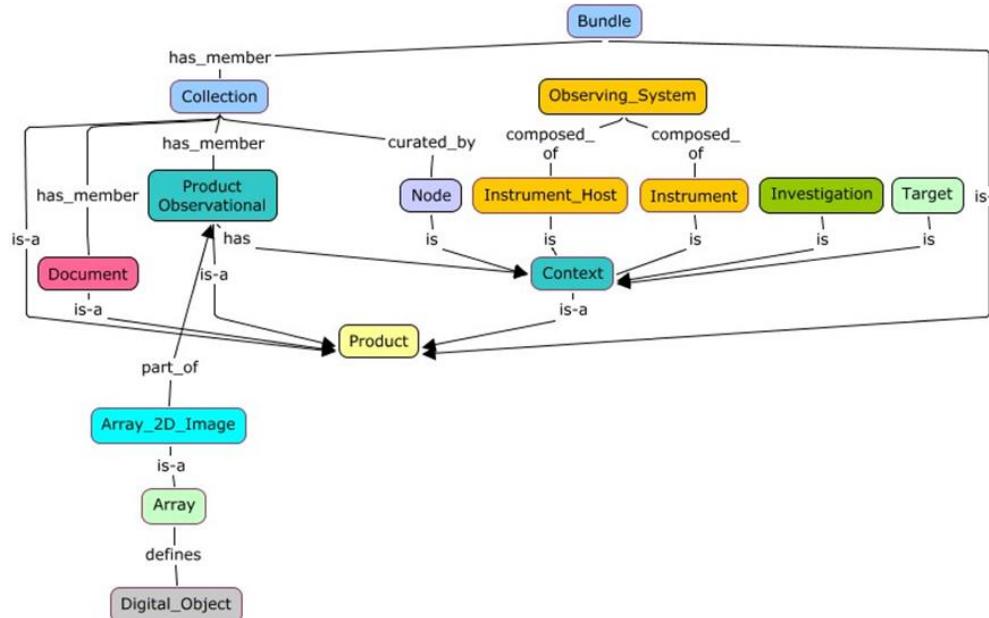
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Views

Community's View



Information Modeler's View



Repository View

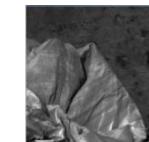
Product

Tagged Data Object

(Information Object)

```
<local_identifier>MPFL_M_IMP_IMAGE</local_identifier>
<offset unit="byte">0</offset>
<axes>2</axes>
<axis_index_order>Last_Index_Fastest</axis_index_order>
<encoding_type>Binary</encoding_type>
<Element_Array>
  <data_type>SignedMSB4</data_type>
  <unit>pixel</unit>
</Element_Array>
<Axis_Array>
  <axis_name>Line</axis_name>
  <elements>248</elements>
  <sequence_number>1</sequence_number>
</Axis_Array>
<Axis_Array>
  <axis_name>Sample</axis_name>
  <elements>256</elements>
  <sequence_number>2</sequence_number>
</Axis_Array>
</Array_2D_Image>
```

Describes



Data Object



Roles

- Definitions for:
 - *data structure (format)*
 - *science interpretation of the data*
 - *context within which the data was captured, processed, and archived*
 - *relationships between the data*
- Expert knowledge from each of the science disciplines.
- Single authoritative source for the data standards.
- Drives the PDS4 infrastructure by providing:
 - *A sharable, stable, and organized structure of information requirements.*
 - *Formal definitions that are suitable for configuring and generating code.*
- Remains independent of its implementation



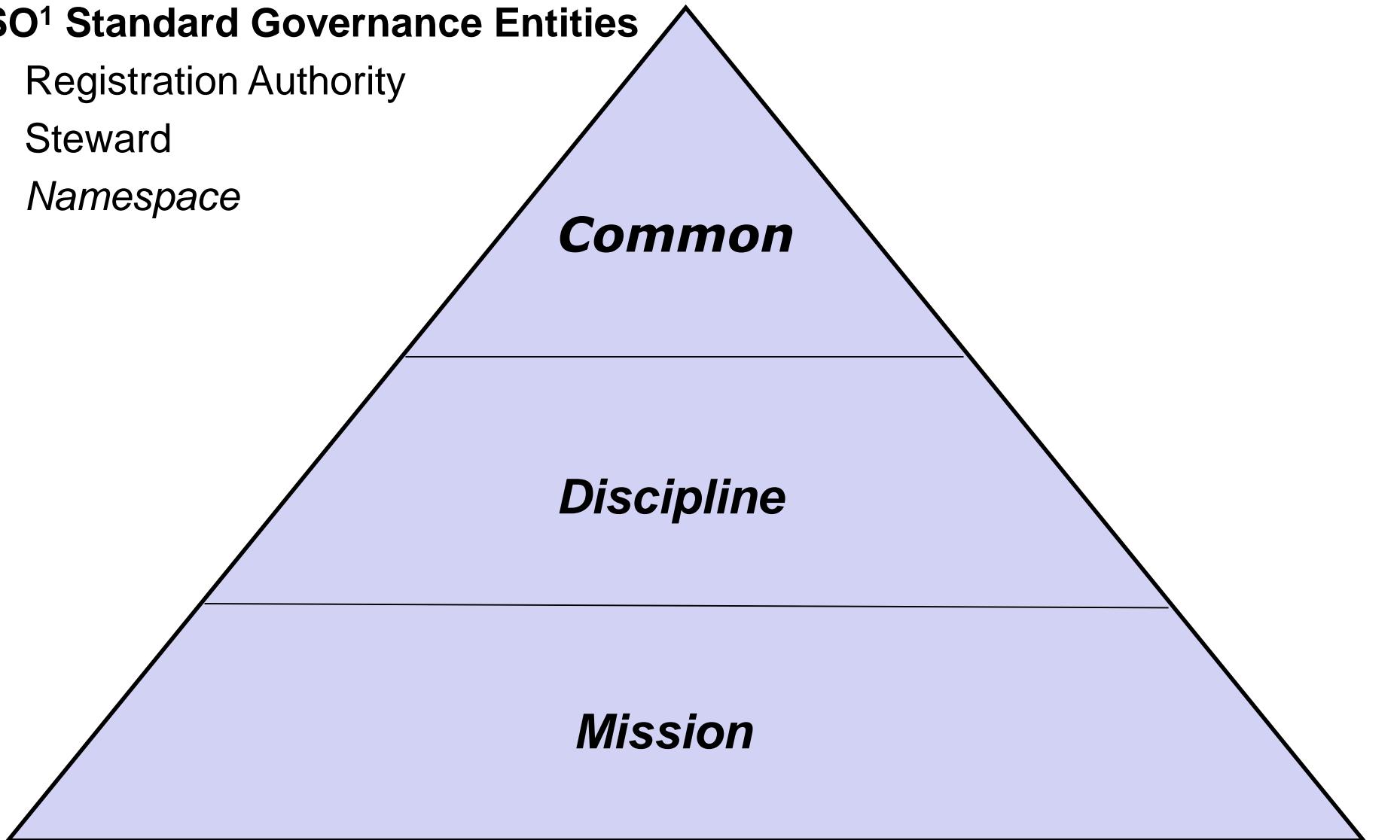
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Governance

ISO¹ Standard Governance Entities

- Registration Authority
- Steward
- Namespace





- Benefits - **Interoperability**

- Software and services support interoperability at multiple levels.
 - *The information requirements for metadata processing are largely available in the dictionaries.*
 - *Processing for data objects is driven by the metadata in the dictionaries.*
 - *The Common dictionary enables interoperability across the entire community*
 - *The Discipline dictionaries enable interoperability across science and engineering disciplines*
 - Cartography and Geometry
 - Rings vs Atmospheres
 - *The Mission dictionaries provide a local vocabulary for a mission or project.*



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Minimize Impact of Change

- An independent Information Model disentangles the information system from the implementation technology.
 - *Technology changes at a rate different from the domain.*
 - *Technology is designed to be configured.*
- Multi-level governance allows the classification of changes and limits impact.
 - *The Common dictionary is relatively stable*
 - *The Mission and Project dictionaries are localized and more flexible.*



Extensions

- Model extensions inherit the full capability of the parent model, while retaining the ability to add customized capability.
 - The Common dictionary defines bundles, collections, products, common classes and attributes, data types, and units of measure
 - The Discipline and Mission use the common classes and attributes, data types and units of measure.
- Mission and project dictionaries can be cloned for new purposes.



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- Applications -

Identification_Area
Logical_Identifier
Version_Id

Observation_Area
Time_Coordinates
Primary_Result_Summary
Investigation_Area
Observing_System
Target_Identification

Discipline_Area
Mission Area

Reference_List
Internal_Reference
External_Reference

File_Area_Observational
File
Header
Array_2D_Image



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Product Templates and Labels

```
<Product_Observational
  <Identification_Area>
    <logical_identifier>urn:nasa:pds:example.dph.sampleproducts:exampleproducts:array2d_image ...
    <version_id>1.0</version_id>
    <title>MARS PATHFINDER LANDER Experiment</title>

    <Array_2D_Image>
      <local_identifier>MPFL-M-IMP_IMG_GRAYSCALE</local_identifier>
      <offset unit="byte">0</offset>
      <axes>2</axes>
      <axis_index_order>Last Index Fastest</axis_index_order>

      <Element_Array>
        <data_type>UnsignedMSB2</data_type>
        <unit>data number</unit>
        <scaling_factor>1</scaling_factor>
        <value_offset>0</value_offset>
      </Element_Array>
      <Axis_Array>
        <axis_name>Line</axis_name>
        <elements>248</elements>
        <sequence_number>1</sequence_number>
      </Axis_Array>
      <Axis_Array>
        <axis_name>Sample</axis_name>
        <elements>256</elements>
        <sequence_number>2</sequence_number>
```



Structure, Semantics, and Rules

```
<xs:complexType name="Array_2D_Image">
  <xs:annotation>
    <xs:documentation>The Array 2D Image class is an extension of the
      Array 2D class and defines a two dimensional
      image.</xs:documentation>
  </xs:annotation>
  <xs:complexContent>
    <xs:extension base="pds:Array_2D">
```

```
<xs:complexType name="Array">
  <xs:annotation>
    <xs:documentation>The Array class defines a homogeneous N-dimensional array of scalars. ...
  </xs:annotation>
  <xs:complexContent>
    <xs:extension base="pds:Byte_Stream">
      <xs:sequence>
        <xs:element name="offset" type="pds:offset" minOccurs="1" maxOccurs="1"></xs:element>
        <xs:element name="axes" type="pds:axes" minOccurs="1" maxOccurs="1"></xs:element>
        <xs:element name="axis_index_order" type="pds:axis_index_order" minOccurs="1" ...>
        <xs:element name="description" type="pds:description" minOccurs="0" maxOccurs="1"> ...
        <xs:element name="Element_Array" type="pds:Element_Array" minOccurs="1" ...>
        <xs:element name="Axis_Array" type="pds:Axis_Array" minOccurs="1" ...>
```

```
<sch:pattern>
  <sch:rule context="pds:Array/pds:axis_index_order">
    <sch:assert test=". = ('Last Index Fastest')">
      The attribute pds:axis_index_order must be equal to the value 'Last Index Fastest'.</sch:assert>
```

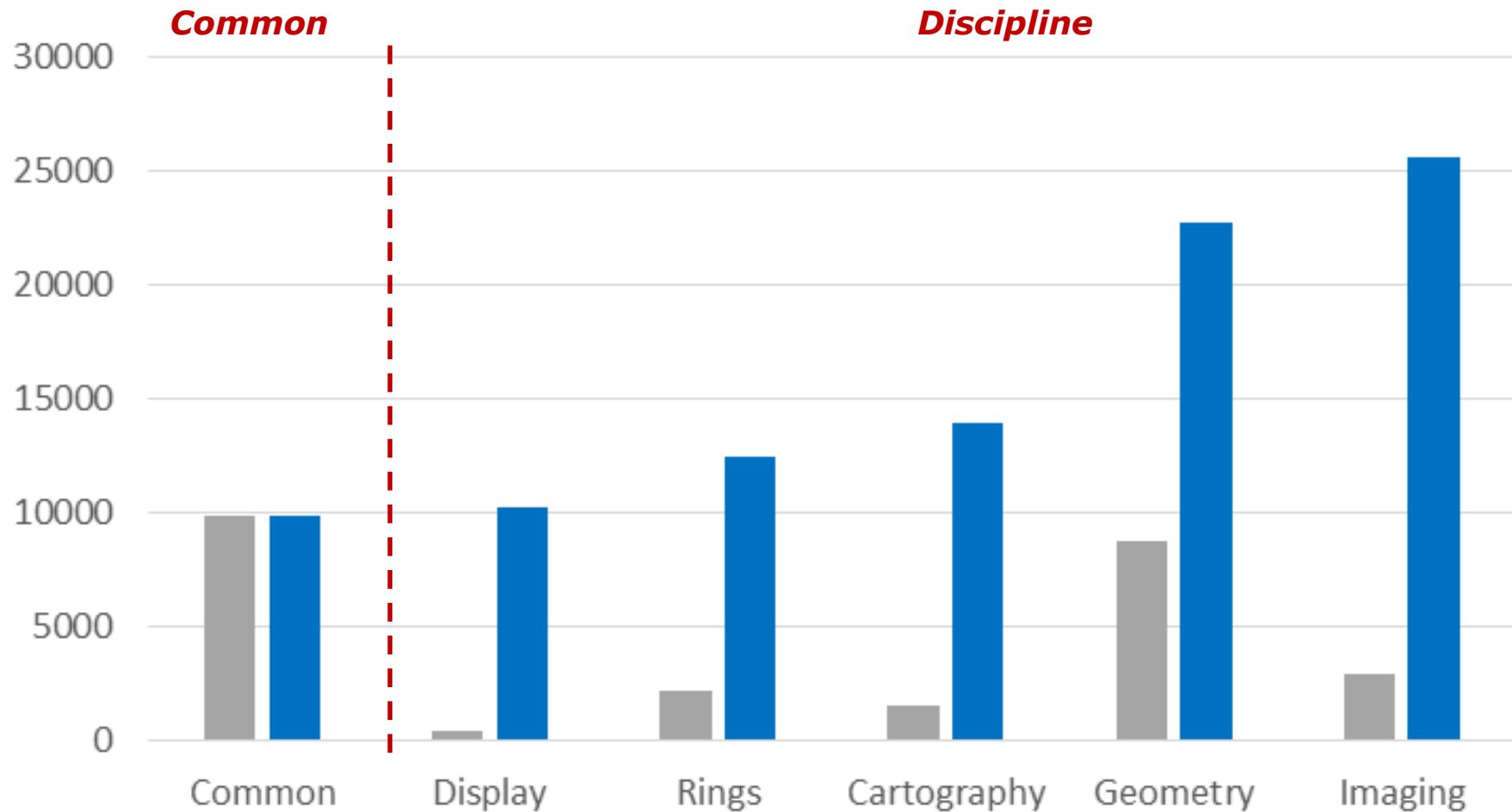


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Validation

Lines of XML Schema and Schematron





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PLAID

plaид.jpl.nasa.gov/plaid_beta/wizard.php?version=1800

PDS Label Assistant for Interactive Design (PLAID)

New Mission Label Preview Exit

✓ Investigation Area

✓ Internal Reference

✓ Observing System

✓ Observing System Component

✓ Target Identification

✓ File Area Observational

✓ File

✓ Array 2D

✓ Axis Array

✓ Element Array

✓ Discipline Dictionaries

✓ Mission Specifics

18. Export

Label Template Preview

```
1 <?xml version="1.0"?>
2 <Product_Observational xmlns="http://pds.nasa.gov/pds"
3   <Identification_Area>
4     <logical_identifier></logical_identifier>
5     <version_id></version_id>
6     <title></title>
7     <information_model_version></information_mod
8     <product_class></product_class>
9   </Identification_Area>
10  <Observation_Area>
11    <Time_Coordinates>
12      <start_date_time></start_date_time>
13      <stop_date_time></stop_date_time>
14    </Time_Coordinates>
15    <Investigation_Area>
16      <name></name>
17      <type></type>
18      <Internal_Reference>
19        <reference_type></reference_type>
```

Filename: label_template.xml Export

Previous Finish

i
Your label template is complete!

Before exporting your label, please review the preview to ensure your label template is accurate.

After that, please enter a valid* filename for your label template and then click 'Export'. The file will be available in your Downloads folder.

*Filename may have characters, digits, underscores, and hyphens. It must start with a character and end with an .xml extension.



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Term Mapping

```
<Terminological_Entry_SKOS>
  <identifier>pds3:ARM_ARTICULATION_STATE.ARTICULATION_DEVICE_ANGLE_NAME
  <namespace_id>pds3</namespace_id>
  <steward_id>pds3</steward_id>

  <title>ARM_ARTICULATION_STATE.ARTICULATION_DEVICE_ANGLE_NAME</title>

  <description>...</description>\

  <referenced_identifier>0001_NASA_PDS_1.
    insight.Instrument_Parameters.insight.index_value_angle

  <skos_relation_name>closeMatch</skos_relation_name>

  <model_object_id>null</model_object_id>
  <model_object_type>attribute</model_object_type>
  <instance_id>npds:Observation_Area/pds:Discipline_Area/geom:Geometry
    /geom:Geometry_Lander/geom:Articulation_Device_Parameters[1]
    /geom:Device_Angle/geom:Device_Angle_Index/geom:index_value_angle
</Terminological_Entry_SKOS>
```



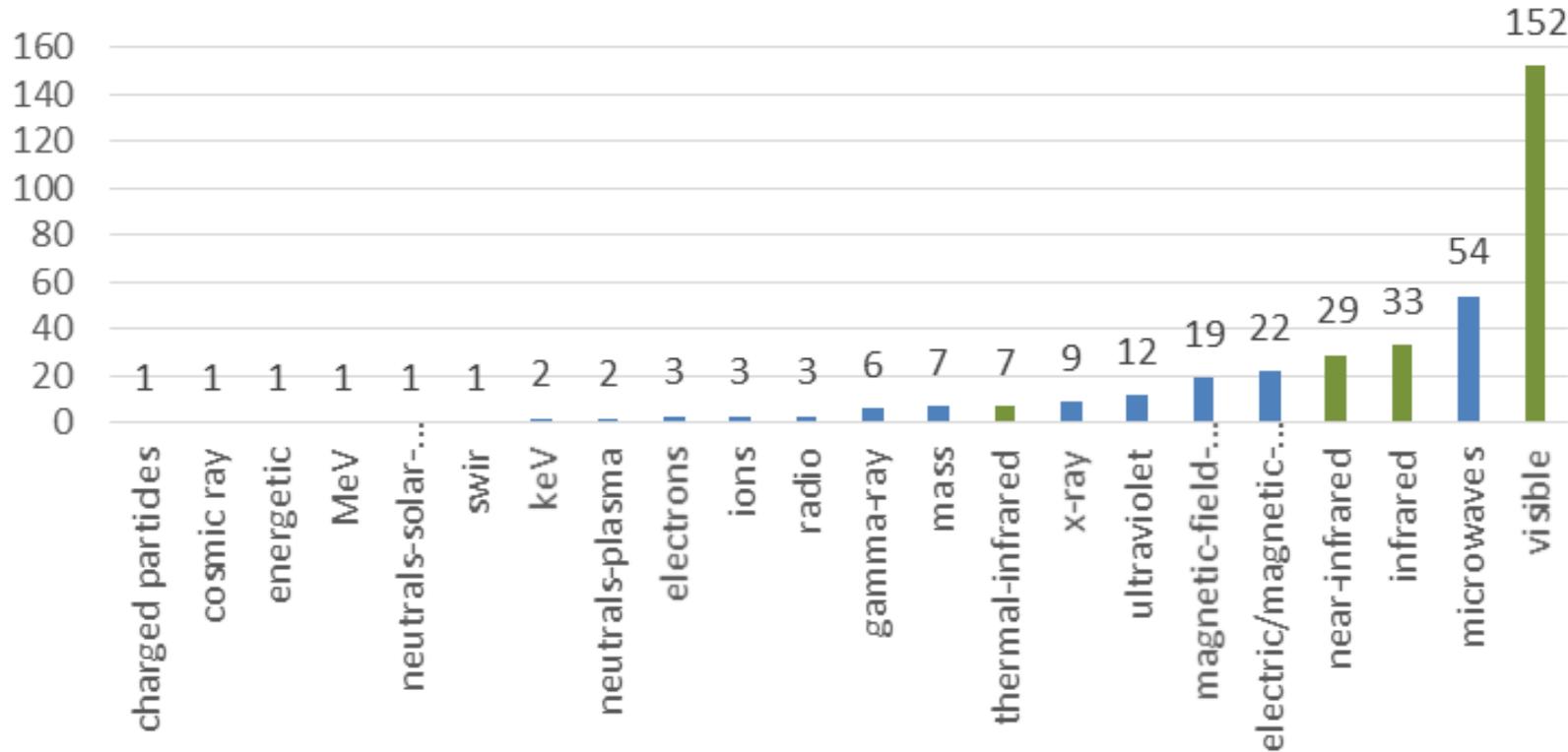
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Analytics

Identify data products within the Planetary Data System (PDS) Archive that are scientifically useful for the Exoplanet project.

Number Of Instruments per
Energy/Wavelength Facet





Conclusion

- The PDS4 Information Model is the core of the PDS4 Information System.
 - *Provides the Information Requirements for the system.*
 - *Use to capture and validate the metadata required to define and describe the science data objects in the archive.*
 - *Used to configure common software and services*
- Used as a prototype in the development of an implementable architecture for Trusted Digital Repositories.
 - *Open Archival Information System (OAIS) Reference Model – ISO-14721*



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Thank You

Questions and Answers

PDS homepage: <https://pds.nasa.gov/>

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Backup



Example

urn:nasa:pds:sbn_samples:fits:helloworld

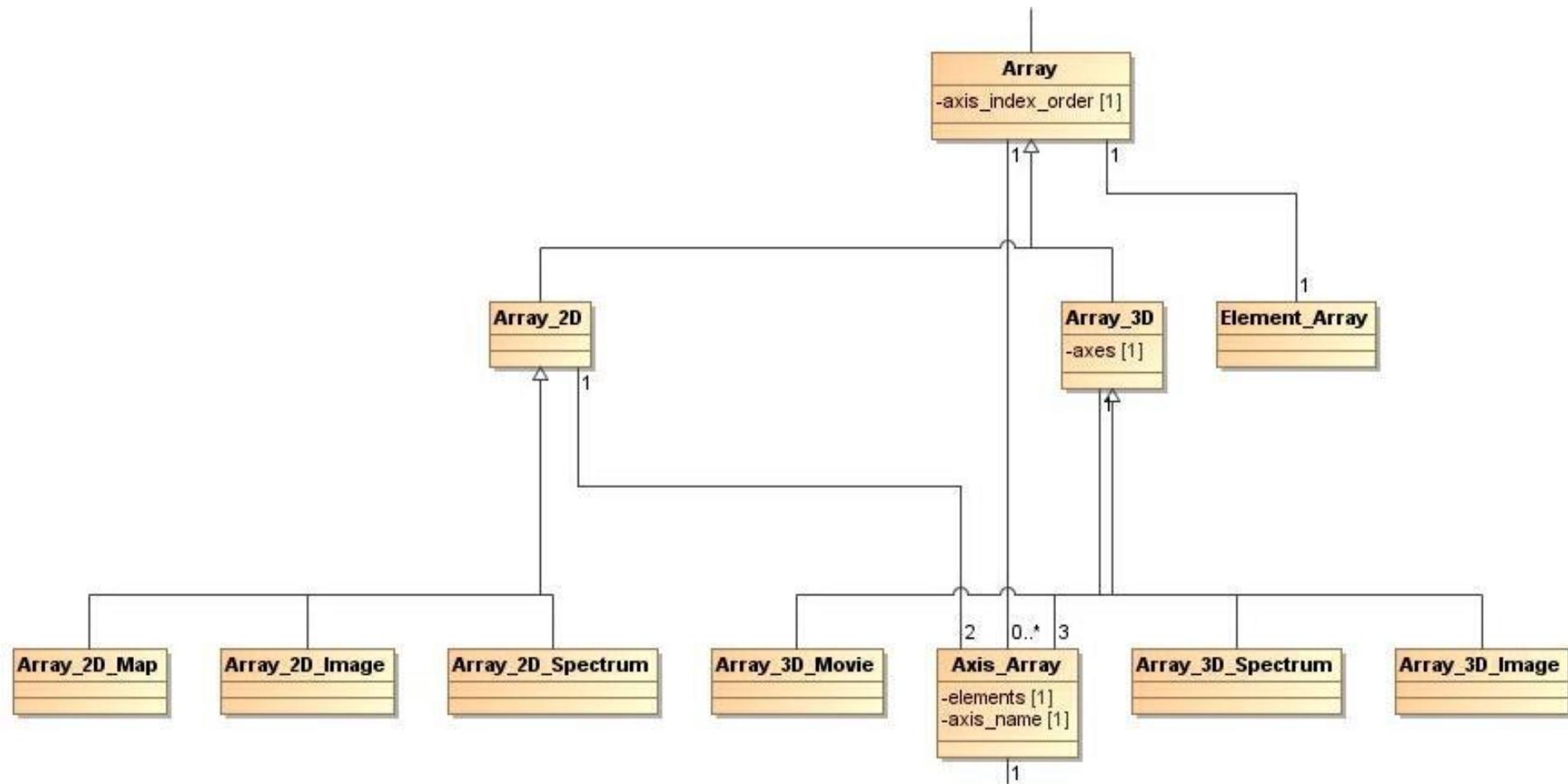
```
<Array_2D_Image>
    <local_identifier>Bob</local_identifier>
    <offset unit="byte">2880</offset>
    <axes>2</axes>
    <axis_index_order>Last Index Fastest</axis_index_order>
    <Element_Array>
        <data_type>UnsignedByte</data_type>
    </Element_Array>
    <Axis_Array>
        <axis_name>Line</axis_name>
        <elements>480</elements>
        <sequence_number>1</sequence_number>
    </Axis_Array>
    <Axis_Array>
        <axis_name>Sample</axis_name>
        <elements>640</elements>
        <sequence_number>2</sequence_number>
    </Axis_Array>
</Array_2D_Image>
```



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UML Class Diagram





Dictionaries

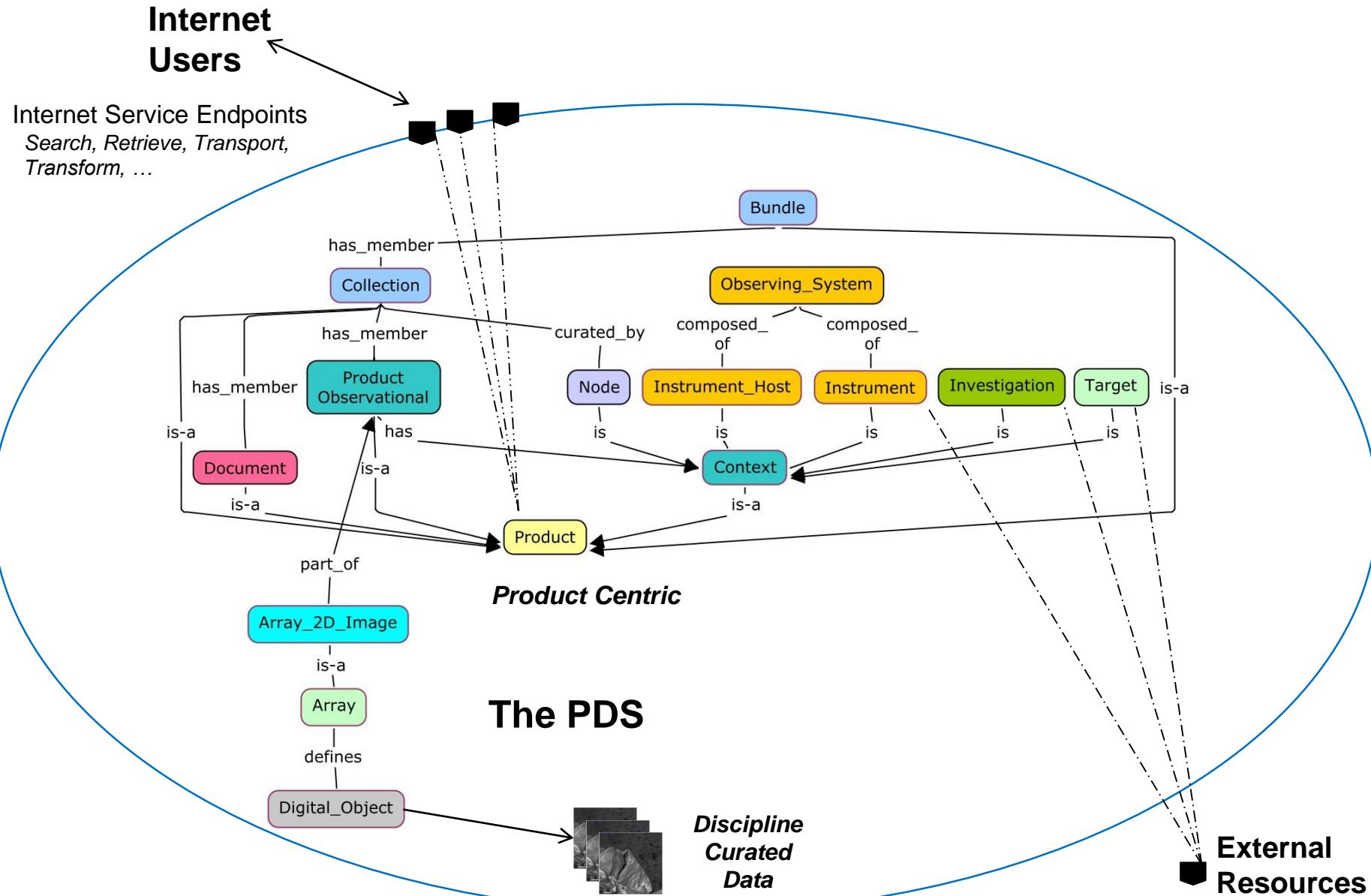
Registration Authority	Steward Id	Namespace Id*	XML Schema Namespace	Logical Identifier Prefix	Governance Level	Steward	Oversight
0001_NASA_PDS_1	lds	lds	http://pds.nasa.gov/pds4/lds/v1	urn:nasa:lds:	Common	PDS EN Node*****	CCB
0001_NASA_PDS_1	atm	atm	http://pds.nasa.gov/pds4/atm/v1	urn:nasa:lds:	Discipline	PDS ATM Node	
0001_JAXA_DARTS_1	darts	darts	http://pds.nasa.gov/pds4/darts/v1	urn:jaxa:darts:	Discipline	DARTS (JAXA)	
0001_NASA_PDS_1	en	dph	http://pds.nasa.gov/pds4/dph/v1	urn:nasa:lds:	Discipline	PDS EN Node	
0001_NASA_PDS_1	geo	geo	http://pds.nasa.gov/pds4/geo/v1	urn:nasa:lds:	Discipline	PDS GEO Node	
0001_NASA_PDS_1	geo	geom	http://pds.nasa.gov/pds4/geom/v1	urn:nasa:lds:	Discipline	PDS GEO Node	
0001_NASA_PDS_1	img	cart	http://pds.nasa.gov/pds4/cart/v1	urn:nasa:lds:	Discipline	PDS IMG Node	
0001_NASA_PDS_1	img	disp	http://pds.nasa.gov/pds4/disp/v1	urn:nasa:lds:	Discipline	PDS IMG Node	
0001_NASA_PDS_1	img	img	http://pds.nasa.gov/pds4/img/v1	urn:nasa:lds:	Discipline	PDS IMG Node	
0001_NASA_PDS_1	naif	naif	http://pds.nasa.gov/pds4/naif/v1	urn:nasa:lds:	Discipline	PDS NAIF Node	
0001_NASA_PDS_1	ops	lds	http://pds.nasa.gov/pds4/ops/v1	urn:nasa:lds:	Discipline	PDS EN Node	
0001_NASA_PDS_1	ppi	alt	http://pds.nasa.gov/pds4/alt/v1	urn:nasa:lds:	Discipline	PDS PPI Node	
0001_NASA_PDS_1	ppi	particle	http://pds.nasa.gov/pds4/particle/v1	urn:nasa:lds:	Discipline	PDS PPI Node	
0001_NASA_PDS_1	ppi	ppi	http://pds.nasa.gov/pds4/ppi/v1	urn:nasa:lds:	Discipline	PDS PPI Node	
0001_NASA_PDS_1	ppi	wave	http://pds.nasa.gov/pds4/wave/v1	urn:nasa:lds:	Discipline	PDS PPI Node	
0001_ESA_PSA_1	psa	psa	http://psa.esa.int/psa/v1	urn:psa:esa:	Discipline	ESA PSA	
0001_NASA_PDS_1	rings	rings	http://pds.nasa.gov/pds4/rings/v1	urn:nasa:lds:	Discipline	PDS Rings Node	
0001_NASA_PDS_1	rs	rs	http://pds.nasa.gov/pds4/rs/v1	urn:nasa:lds:	Discipline	PDS RS Node	
0001_ROS_RSSA_1	rssa	rssa	http://pds.nasa.gov/pds4/rss/v1	urn:ros:rssa:	Discipline	RSSA (IKI)	
0001_NASA_PDS_1	sbn	sbn	http://pds.nasa.gov/pds4/sbn/v1	urn:nasa:lds:	Discipline	PDS SBN	
0001_NASA_PDS_1	sbn	sp	http://pds.nasa.gov/pds4/sp/v1	urn:nasa:lds:	Discipline	PDS SBN	
0001_NASA_PDS_1	atm	ladee	http://pds.nasa.gov/pds4/mission/ladee/v1	urn:nasa:lds:	Mission	PDS ATM Node	
0001_NASA_PDS_1	atm	ladee	http://pds.nasa.gov/pds4/ladee/v1	urn:nasa:lds:	Mission	PDS ATM Node	
0001_NASA_PDS_1	geo	insight	http://pds.nasa.gov/pds4/mission/insight/v1	urn:nasa:lds:	Mission	PDS GEO Node	
0001_NASA_PDS_1	img	mgs	http://pds.nasa.gov/pds4/mission/mgs/v1	urn:nasa:lds:	Mission	PDS IMG Node	
0001_NASA_PDS_1	img	mpf	http://pds.nasa.gov/pds4/mission/mpf/v1	urn:nasa:lds:	Mission	PDS IMG Node	
0001_NASA_PDS_1	sbn	orex	http://pds.nasa.gov/pds4/mission/orex/v1	urn:nasa:lds:	Mission	PDS SBN	
0001_NASA_PDS_1	ppi	mvn	http://pds.nasa.gov/pds4/mission/mvn/v1	urn:nasa:lds:	Mission	PDS PPI Node	
0001_NASA_PDS_1	ppi	mvn	http://pds.nasa.gov/pds4/mvn/v1	urn:nasa:lds:	Mission	PDS PPI Node	
0001_NASA_PDS_1	sbn	bopps	http://pds.nasa.gov/pds4/mission/bopps/v1	urn:nasa:lds:	Mission	PDS SBN	



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Core Components in Context





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The PDS4 Information Model

